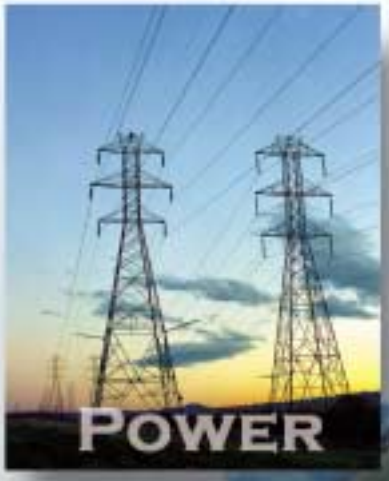
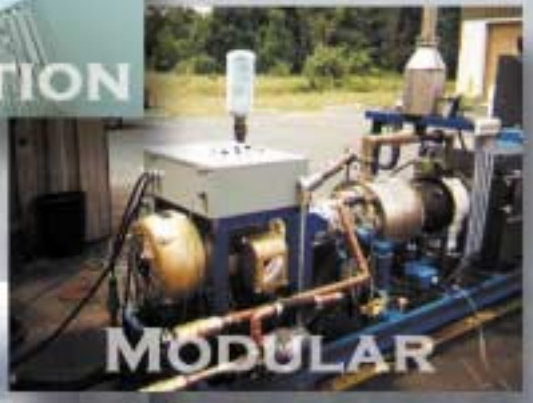
DOE Biopower Program





A Strategy for the Future

Office of Energy Efficiency and Renewable Energy • U.S. Department of Energy

Message from the Biopower Program

Contents

This document presents an overview of the U.S. Department of Energy Biopower Program and the nation's biopower industry, and proposes steps to increase the use of this form of renewable energy produced from plant and organic material. Biopower is an important contributor to today's economy, providing 7,000 megawatts of the nation's electric generating capacity. Biopower also offers increased energy self-reliance, employment generation, improved air quality, and reduced greenhouse gas emissions. Major changes, such as the massive restructuring of the electric utility industry, advances in biopower generation technology and plant biotechnology, improved resource processing, and increased environmental concerns, promise new opportunities and challenges. This *Strategy for the Future* establishes a framework for action that will lead to significant growth by the biopower industry in the 2020 timeframe. This posture will also permit the biopower industry to compete economically, and at the same time improve the sustainability of natural resources, environmental quality, and national security.

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Introduction

Biomass energy—the energy contained in plants and organic matter—is an important resource for power generation in the United States. Currently, various forms of biomass energy account for nearly three percent of the energy consumed in the U.S. and provide significant economic opportunities and environmental benefits to the nation. Increasing our use of biomass resources improves the national balance of trade and encourages domestic economic growth and job creation. Furthermore, the use of biomass, particularly to generate electricity, helps significantly reduce greenhouse gas emissions.

The U.S. Department of Energy (DOE) Biopower Program is working to meet our national energy needs, while simultaneously reducing conventional energy dependence, protecting our environment, and improving our rural economy. This Biopower Plan represents a broad-based effort to articulate the key issues related to the expanded development and utilization of biopower. It defines the role of the Federal Government and U.S. industry in partnering to accomplish strategic goals. The three overarching goals of the Biopower Plan are to:

- Establish partnerships with industry;
- Encourage the highest standard of environmental stewardship; and
- Enhance economic development opportunities.

The DOE Biopower Program is committed to a combination of near-, mid-, and long-term R&D. This integrated research focus encourages the commercialization of the most economic near-term options for new biomass power generation while laying the groundwork for advanced technologies. In addition, the Program is collaborating with DOE's Bioenergy Initiative to foster an integrated bioenergy industry to produce electric power, fuels, and biobased products (see page 7).

DOE recognizes that there are challenges and opportunities facing increased use of biomass in the United States. These include maximizing the utilization of our biomass resource base; developing new ways in which to maximize the economic, environmental, and national security benefits offered by biopower; and supporting policies and legislative incentives that foster biopower utilization. These will allow biopower to compete with other conventional technologies in new and existing markets. The strategic issues, program goals, and related strategies that are presented in this plan are aimed at overcoming the technological, policy, regulatory, market, and environmental barriers to increased use of biopower in the nation's energy future.

Biomass is the only form of non-hydroelectric renewable energy that is widely available and can be stored and dispatched for use when needed. This energy source accounts for 85 percent of all non-hydroelectric renewable energy generation.

Biopower Mission

In partnership with industry, the Biopower Program will encourage the development and utilization of biopower technologies that are competitive with conventional power systems.

Biopower Vision

The Biopower Program will be a major contributor to meeting or exceeding the Administration's goal of tripling America's use of bioenergy and bioproducts on a sustainable basis.

Biopower Now

At present, the grid-connected biomass electric capacity in the United States is nearly 7 gigawatts (GW). This is about one percent of total domestic generating capacity and about eight percent of non-utility generation capability. The U.S. biopower industry is located primarily where forest residues are plentiful. Consequently, wood wastes account for about 90 percent of all biomass used at present, with agricultural residues providing the balance. The current biopower industry represents an investment base of $15 billion that supports about 66,000 jobs.

The biopower industry typically uses conventional combustion/steam boiler technologies to produce electricity from chipped biomass residues at net efficiencies of 20–25 percent in 15- to 50-megawatt (MW) power plants. Higher efficiencies in the range of 30–35 percent are found in a few utility applications where higher pressure, reheat boilers are used. The incremental changes required to achieve such efficiencies with combustion steam boilers are generally well understood with this mature technology.

Increasing amounts of biomass are also being cofired with coal in power generation boilers. Cofiring biomass in older stoker boilers began more than a decade ago, and more recently, efforts with modern cyclone and pulverized coal boilers have begun. This near-term opportunity to cofire biomass benefits from many efficiency improvements that have been incorporated into these boilers over the years. Coal-fired boilers are distributed in regions where biomass supplies are plentiful, and biomass offers a means to improve environmental profiles while increasing local economic activity in rural areas. For biopower, cofiring offers the means to add efficient generating capacity in a very competitive electric marketplace at a modest capital cost.

During the past five years, power generators have been testing locally grown energy crops as supplemental fuel sources for power generation via cofiring and gasification. These early attempts to integrate crops with residue supplies represent the first steps to a large, sustainable supply of bioenergy.

Recently, some of the major drivers for the biopower industry have changed. During the 1980s, biomass power capacity rapidly expanded as a result of laws mandating that utilities purchase power from suppliers under contracts based on avoided power generation costs

(such as under the Public Utility Regulatory Policies Act of 1978). These contractual prices were substantially higher than current wholesale power prices, and permitted biomass projects to be financed and operated at a profit. Changes in the industry have resulted in lower avoided costs, and as present contracts are concluded, this biomass generation could be at risk.

The electric power industry is also in a period of massive restructuring that adds uncertainty to the biopower industry, including those power producers using biomass resources. The closing of high-cost power plants and the introduction of high-efficiency natural gas facilities is also putting considerable downward pressure on electricity prices. In the United States and some other countries, utilities are breaking into multiple companies that compete for the power generation, transmission, distribution, and on-site elements of the power market. The eventual impacts of these and other trends on individual power producers are not yet clear. However, present trends suggest that profit margins will be even tighter in the future. This atmosphere of heightened competition has already had the effect of reducing the willingness of power companies to take risks with new technology and to use renewable energy resources.

Although this situation presents challenges, the restructuring of the power industry is also providing new opportunities for biopower. Markets are developing for "green power," where electricity from selected generation sources can be sold at higher prices (typically 1–2 cents per kilowatt-hour) than electricity from conventional sources. Through consumer choice, green markets offer opportunities to expand the use and further development of renewable technologies. Increased biopower generation is also being encouraged through Renewable Portfolio Standards (RPS) established by state regulatory agencies. These standards require utilities to provide certain percentages of power, typically 5–10 percent, from renewable sources. Biopower has the opportunity to be a major contributor in meeting and exceeding these requirements. Recognizing that these market-driving forces are currently undergoing clarification, the Biopower Program participates in discussions with environmental groups to resolve issues such as defining "green power" and understanding the public perception of biomass conversion technologies. This could lead to increased acceptance of biopower and resultant grassroots demand for increased deployment.

The Wheelabrator Shasta Energy Company uses stoker boilers and steam turbines to convert wood and agricultural residues into electricity.

All of these technology developments, partnerships, policy initiatives, and environmental mediation efforts provide the necessary foundation for future expansion of both the biopower and biomass fuel supply industries. The DOE Biopower Program Plan builds on this foundation to achieve the Program mission, goals, and strategic objectives.

Federal Biopower Program

The Biopower Program is working with industry, utilities, developers, and universities to reach five national energy policy goals.

Policy Goals

- Improve the efficiency of the energy system;
- Ensure against energy disruptions;
- Promote energy production and use in ways that respect health and environmental values;
- Expand future energy choices; and
- Cooperate internationally on global issues.

Technologies

In this context, various technology options are being provided that will be developed in the near term and into the future.

Cofiring

Cofiring of biomass in high-efficiency coal boilers offers the most promise for quickly addressing carbon emissions goals and developing feedstock supply infrastructures. A recent study (*Scenarios of U.S. Carbon Reductions*, Interlaboratory Working Group) shows that biomass cofiring has the potential to supplement available capacity with at least 8 GW of the nation's coal-fired capacity by 2010, and as much as 26 GW by 2020. In the future, there may be potential to cofire with natural gas. Residues are the most cost-effective feedstocks for the near term, and the fuel market generated by their use will contribute to the infrastructure needed for eventual introduction of energy crops. Recent analyses indicate that sufficient residues exist in the United States to support nearly 20 GW of cofiring with only minimal tax or other incentives. Although a number of the Program partners are producing commercial power from biomass, several research issues must be resolved, including how to prepare, inject, and control biomass combustion in a coal-fired boiler to maximize efficiency and minimize emissions. Research is under way with industrial partners to improve methods for combining biomass and coal in pulverized-coal systems. Power companies also must find ways to implement cofiring on a wide scale, but these early projects are pointing the way for the power industry. Collaboration with current and emerging power production companies that use combustion technologies to generate biopower is continuing to support the industry and refine cofiring technologies.

Gasification

New technology developments on advanced biomass gasification appear to offer significant

Cofiring

For utilities and power generating companies with coal-fired capacity, cofiring with biomass may represent one of the least-cost renewable energy options. Cofiring involves mixing biomass with coal in an existing fuel feed and burning them together, or providing a separate boiler feed for the biomass. Either way, the biomass displaces some coal, perhaps as much as 15 percent. According to a recent report prepared for the Department of Energy by five National Laboratories, domestic biomass generation capacity could reach 20–30 GW by the year 2020 by cofiring at existing coal-fired plants.

potential for high-efficiency generation of biopower, both in integrated gasification combined-cycle (IGCC) and cofiring operations. Gasification of energy crops and residues for use in gas turbines provides the potential to double electricity generation efficiencies of biomass production facilities (35–40 percent up from 20 percent), and lowers biomass power.

Modular Systems

Working with industry, DOE's Small, Modular Systems Project is developing efficient and clean small biopower systems. The Thermochemical Conversion Users Facility at NREL offers researchers a testing facility to establish gas quality composition for engines and other prime movers such as fuel cells and microturbines. These specifications help biomass technology and prime mover developers better understand each other's needs.

The Biopower Program is building on advances in gasification technology for coal and black liquor, which are occurring as a result of investments by the power, manufacturing, and paper industries. Partnerships with industry are in place to test gasifier and gas turbine designs, while research continues to test new designs, especially for gas cleanup. Although gasification is believed to provide the best technology for producing a clean turbine fuel, other processes, including combustion/gas turbine and pyrolysis oil/gas turbine systems, are also under consideration.

Modular Systems

To take advantage of increasing interest in distributed power (generation of power at or near the points of consumption with or without connection to the existing power grid), the Biopower Program has instituted technology development and deployment efforts for modular biopower generation. Small, modular biomass work focuses on demonstrating the economic and technical viability of advanced biomass conversion systems with capacities less than 5 MW. Various biomass conversion technologies are being assessed to fuel micro-turbines, Stirling engines, and gas engines. These innovative technologies are targeted at capturing a share of the growing global potential for distributed generation.

Gasification

Biomass gasification and providing the means to connect gasifiers to advanced electric power systems encompass one of the key R&D areas for DOE's Biopower Program. Wood gasification converts wood into a gaseous, energy-intensive fuel source that can be used in high-efficiency gas turbines to generate electric power at low cost. Using biomass to fuel gas turbine combined-cycle systems will nearly double the electric generating efficiency typical of today's biopower industry. As gas turbines are used in baseload power generation, peak shaving, and distributed power generation, biomass gasification could utilize existing fossil fuel technology.

Bioenergy Feedstock Development

In parallel with research efforts to advance power technologies, the Biopower Program is fostering development of an economical and reliable biomass fuel supply. Although wood and other residues are used today as biomass feedstocks, larger quantities may be needed to meet a growing demand for sustainable electricity.

The Bioenergy Feedstock Development Program located at Oak Ridge National Laboratory is testing and developing fast-growing, environmentally-acceptable trees and grasses that could be grown specifically for use as fuels. Research on plant genetics and biological processes, and on environmental effects of energy crop production, will result in the knowledge needed to create environmentally sound, fast growing crop production systems. The Program has screened more than 125 tree and non-woody species and selected a limited number of model species for development as energy crops including hybrid poplar, hybrid willow, and switchgrass. These energy crops will be planted primarily on unused agricultural lands.

Technology Supporting Elements

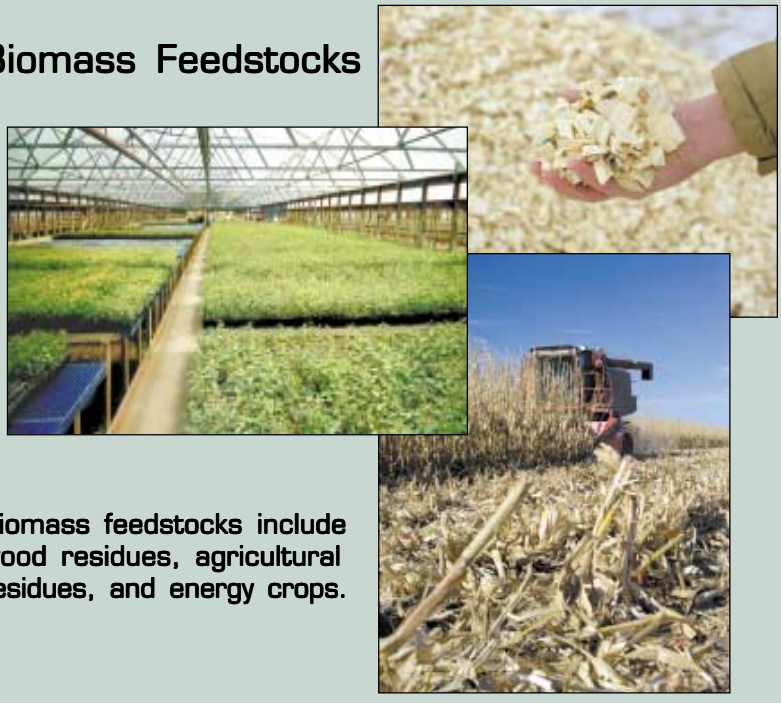
Energy Conversion Research

Recognizing the critical underpinnings needed to attain technological development, the Biopower Program supports scientific research on the chemical and thermodynamic mechanisms of advanced biomass conversion technologies. These activities are conducted at DOE's Experimental Facilities including the National Renewable Energy Laboratory (NREL), Sandia National Laboratory, the National Energy Technology Laboratory, and others.

Regional Biomass Energy Program

The Biopower Program also supports DOE's Regional Biomass Energy Program (RBEP), which addresses technology transfer, industry support, and conversion technologies by leveraging local resources with DOE funds. The RBEP's major focus is to transfer current, reliable information to potential biomass users. Emphasis is placed on technologies best suited to near-term use. The RBEP carries out its mission through an extensive network of local, state, and national government organizations, and partnerships with private industry. RBEP has offices in five regions of the continental United States: the Northeast, Southeast, Great Lakes, Northwest, and West.

Biomass Feedstocks



Biomass feedstocks include wood residues, agricultural residues, and energy crops.

International Activities

The Biopower Program also seeks to advance worldwide progress in the research, development, and demonstration of energy technologies to efficiently utilize bioenergy resources. The Program uses mechanisms including government-to-government (bilateral) agreements (Canada/U.S. and Finland/U.S.) to promote biomass technology exchange such as modular systems. DOE also participates in the International Energy Agency Bioenergy Agreement, which addresses a host of technologies through demonstrations and information exchange.

Bioenergy Initiative

DOE is collaborating with other Federal organizations as part of a national partnership known as the Bioenergy Initiative to develop an integrated industry to produce power, fuels, and chemicals from biomass.

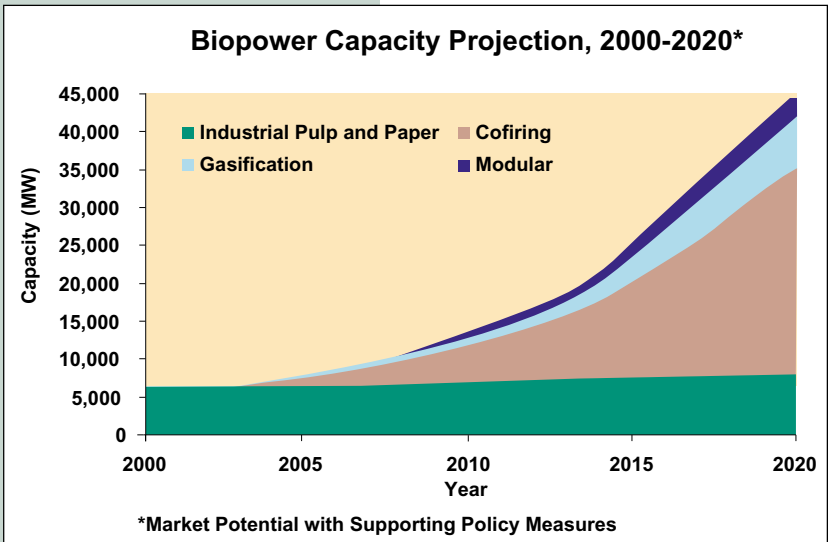
On August 12, 1999, the President issued an Executive Order on Biobased Products and Bioenergy that will coordinate Federal efforts to accelerate the development of 21st century biobased industries. These industries will use trees, crops, agricultural, forest, and aquatic resources to make an array of commercial products including fuels, electricity, chemicals, adhesives, lubricants, and building materials.

In a separate Executive Memorandum on the same issue, the President set a goal of tripling U.S. use of biobased products and bioenergy by 2010. In the President's remarks at the Executive Order signing ceremony, he stated that reaching the tripling goal "would generate as much as $20 billion a year in new income for farmers and rural communities, while reducing greenhouse gas emissions by as much as 100 million tons a year —the equivalent to taking more than 70 million cars off the road." DOE believes a focused, visible, and international effort can make the United States a world leader in the production of bioenergy products.

Biomass: Growing an Integrated Industry

Opportunities

There is potential for biopower to grow to an industry with nearly 45,000 MW of capacity, employing 190,000 persons (mainly in rural areas), and producing 225–300 billion kWh of electricity by the year 2020. The attendant benefits of such capacity are reduced greenhouse gas and other emissions, decreased landfill burden, improved water quality, a more productive agricultural sector, enhanced rural economies, and bioproduct industries.



Source: DOE Biopower Program Projections

As discussed in the preceding section, technological advances offer a huge potential to increase the efficiency and reduce the capital intensity of commercial biopower plants, thus making them more competitive. Efficiency gains have a multiplier effect all the way through the supply chain by requiring less feedstock per kilowatt-hour of electricity produced. This increase in the productive use of biomass feedstocks will reduce the amount of land and other inputs needed per kilowatt-hour for energy crop production.

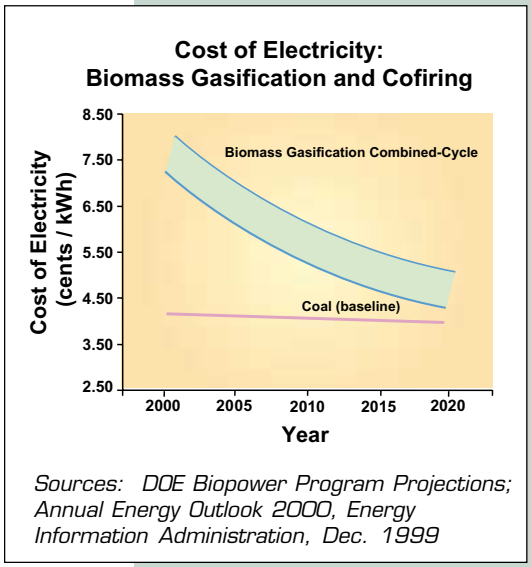
Solutions Throug

DOE recognizes the important role of industry-led partnerships and the ne realized. The Biopower Program provides opportunities for stakeholders to and technology to work. The role of the Program is not to choose commerc technologies. The Program uses tools such as program opportunity notices teams within industry to conduct RD&D on cofiring, gasification, modular s leading to the implementation of commercially-viable projects, and enhanc energy marketplaces.

New initiatives underway, such as the Bioenergy Initiative and the Bioener government and industry and across industry sectors on key RD&D — rang through applied research on feedstock production and processing, to field and biobased industrial and consumer products.

Environmental, social, and political factors may also facilitate the expansion of biopower. Replacing fossil fuels with biomass leads to global benefits, such as reduced emissions of greenhouse gases including carbon dioxide (CO_2) and stimulating economic development in rural rather than urban settings. Biopower is increasingly sought as a supplemental fuel for coal-fired power generation because of its ability to offset sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions, as well as reduce emissions such as lead and mercury.

Biopower also can alleviate a number of waste-related problems. By diverting agricultural and clean urban wood waste from landfills, while producing energy, bioenergy facilities represent a solid waste disposal option in many states. Stronger enforcement of landfill diversion rules, to ensure that clean materials are either recycled or reused as fuel for energy production, may accelerate this use. While the practice of in-field burning is generally banned due to concerns over air pollution, agricultural field residues represent another near-term opportunity for biopower use. National attention is being drawn to problems associated with livestock and poultry production, where large populations of animals are impacting the environment. The use of animal manure or litter as a biomass feedstock could make use of an environmental hazard to produce energy. Other opportunities for biopower include the use of forest residues in energy facilities as an alternative forest management tool. Important water quality benefits are achieved when energy crops are used for watershed improvements, such as vegetation filters for the treatment of municipal waste water and as buffer strips for the interception of fertilizer run-off from food crops to watercourses.



Sources: DOE Biopower Program Projections; Annual Energy Outlook 2000, Energy Information Administration, Dec. 1999

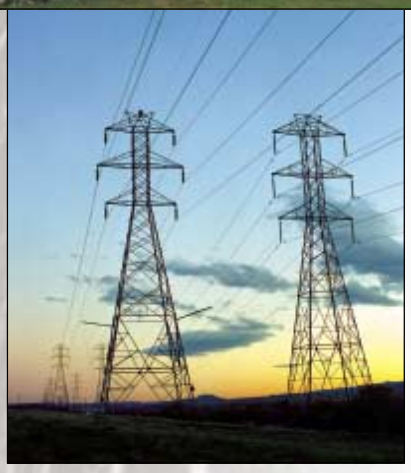
The potential economic benefits of biopower are enormous—not only for farmers who raise the raw material, but for the forest product industries, chemical manufacturers, power companies, and entrepreneurs. By encouraging the development of the biomass supply infrastructure, biopower can help build a pathway for bringing biobased products from farms, forests, and laboratories to the marketplace. Moreover, the development of legislation and other incentives that support biomass power production, as well as reward it for environmental services and other valuable benefits provided to society, will help to ensure a brighter future for this energy source.

h Partnerships

ed for multi-agency collaboration if the full potential of biopower is to be combine interests to create new ventures that put biomass resources cial winners but to serve as a catalyst to accelerate the acceptance of new and solicitations to encourage the development and collaboration of systems, and feedstock development. These joint venture projects are ed penetration of these technologies into the national and international

rgy Executive Order, are working to foster greater cooperation between ging from basic research to tailor new crop varieties for biorefining, validation of systems and industries that can produce biofuels, electricity,

Key Assumptions



The Biopower Program's plan is based on key assumptions that relate to three major influencing factors:

- Technology
- Markets
- Policy/Regulatory/Environmental

Technology

- Collaboration and partnerships are an increasing trend between the Federal Government and industry.
- Cost reduction and system reliability in technology are having a direct influence on commercial adaptations of biopower systems.
- Environmental and efficiency considerations are playing an increasing role in the development and deployment of biopower systems.

Markets

- "Green power" programs show potential for expanding domestic markets for renewable energy technologies. These programs allow electricity consumers to express a preference and willingness to pay more, if necessary, for cleaner energy sources.
- Biomass power systems offer flexibility and versatility in distributed power markets.

Policy/Regulatory/Environmental

- Increasing environmental concerns have resulted in a greater incorporation of biomass systems in energy planning scenarios worldwide.
- Government programs are increasingly seeking more effective market-driven solutions that achieve environmental goals at the least cost.
- Restructuring of the electric utility industry continues to create opportunities for technology applications through Renewable Portfolio Standards.
- Improving the rural economy creates opportunities in the government and private sector for collaboration with agricultural and forestry organizations, thus enhancing biopower markets for biomass crops.

Program Strategy

Strategic Program Elements

- Technology Advancement: Develop integrated biopower systems in partnership with industry
- Environmental Stewardship: Ensure that biopower embraces the highest environmental standards
- Technology Transfer and Outreach: Provide technical assistance and information on biopower's potential as a sustainable power source for the future

The DOE Biopower Program Plan is embodied in the three strategies described below, including Technology Advancement, Environmental Stewardship, and Technology Transfer and Outreach, which are key elements in achieving the tremendous opportunities that biopower offers. The strategies are implemented through specific actions, which are also described in the Program Plan.

Technology Advancement

The first component is to realize the potential for advancements in biopower technology by: promoting conditions for a significant and early market penetration of biopower; assisting development of low-cost feedstock supplies; and incorporating technology changes into biomass conversion systems. The Program encourages innovation in each facet of biomass conversion, including genetic improvements to feedstock productivity, feedstock processing to improve fuel quality, more efficient conversion of biomass material to electricity, and the management of power production by-products to add value to the system.

Strategy

- Facilitate near-term growth in biopower development by promoting cofiring of biomass with coal in utility boilers.
- Increase the availability and reliability of biomass residues by improving supply technology, and by

Technology Solutions

The Vermont Gasifier project is demonstrating a low-pressure, indirect biomass gasifier connected to the McNeil Generating Station in Burlington, Vermont. This gasifier is considered key in the development of large, industrial- and utility-scale gasifiers. Rated at 200 tons of biomass per day, the low-pressure gasifier operates by heating wood chips to about 830 °C and combusting the resulting clean gas in the McNeil boiler. A gas turbine soon will be added to the system.

The project won the prestigious R&D 100 Award in September 1998 as one of the top scientific achievements of the year. Key partners on the project include: Battelle, Columbus, Ohio; Burlington Electric Department, Burlington, Vermont; Future Energy Resources (FERCO), Atlanta, Georgia; and the National Renewable Energy Laboratory, Golden, Colorado. Pictured at right is a combustor cyclone at the McNeil Generating Station of Burlington Electric Department.

encouraging removal of institutional and regulatory barriers to their use.

- Develop market-competitive conversion technologies by advancing power generation systems, such as gasification combined-cycle and fuel cells, that can produce 30–50 percent more electricity per unit of biomass than traditional systems.
- Encourage the advancement of conversion technologies through modeling and field validations.
- Promote distributed power generation by developing modular systems that can meet the needs of local electric market demands more efficiently by bypassing expensive transmission requirements.
- Expand the total feedstock supply base and improve fuel characteristics by selecting and improving a range of energy crops suitable for a diversity of site types in the United States.
- Reduce the risk of first-of-a-kind cost-shared demonstrations.
- Foster innovative concepts that improve fuel-supply systems, advance power cycle development, and improve conversion processes that can significantly lower electricity costs.

Environmental Stewardship

The second component of the Program strategy is to capture the numerous environmental benefits that biopower offers while simultaneously embracing the highest standards of sustainability and environmental acceptability compatible with the nation's goals.

Strategy

- Realize environmental benefits by growing biomass feedstocks that capture CO_2 through the process of photosynthesis.
- Enhance air quality by having low emissions of SO_2 and NO_x compared to conventional energy sources.
- Increase the ability of biomass feedstock systems to improve soil quality through carbon sequestration and reduce soil erosion, enhance water quality, and improve wildlife diversity.
- Conduct research to ensure that the highest environmental standards are implemented under biopower deployment.
- Quantify environmental benefits through life cycle analyses and soil carbon research modeling.

Environmental Benefits

Fossil fuel combustion generates SO_2, NO_x, and greenhouse gases including CO_2. Although biopower is also generated through a combustion process, it produces fewer emissions than most conventional sources. It can actually improve environmental quality by offsetting fossil fuel use and related emissions and by using wastes that are creating land use problems. Pictured to the left is a gas sampling station on a scrubber at the McNeil Generating Station in Burlington, Vermont where an experimental biomass gasifier operates on wood chips.

Technology Transfer and Outreach

There is the need to educate and disseminate better information on the benefits of biopower to industry, regulators, environmental organizations, and the public to gain appreciation and respect for bioenergy, and in turn, harness support for biopower-friendly policies. Thus, the third component of the Biopower Program strategy is to contribute sound information about the capabilities, benefits, and challenges for the use of biomass to stakeholders, and to show links to markets and foster development and adaptation by the energy industry.

Strategy

- Develop informational/educational material to explain the technologies and benefits of biopower electricity generation.
- Disseminate these educational materials through events sponsored by DOE, state energy offices, utility groups, and the media.
- Seek innovative opportunities to help stakeholders and the public make informed decisions about biopower technologies.
- Provide forums for stakeholder dialogue to discuss and evaluate state-of-the-art biomass technologies, and their role in new business development opportunities.
- Encourage and seek out innovative partnerships among stakeholders to create new ventures that put biomass resources and technology to work.

Outreach on Energy Crops

A group of interested stakeholders tours this hybrid poplar plantation at the Boise Cascade company in Boardman, Oregon. Sites like this offer opportunities to show the potential and benefits of biopower. This stand of hybrid poplar trees, only seven years old, towers over the visitors, illustrating the tremendous growth potential of energy crops.

The period between harvests for woody energy crops varies from 3 to 10 years, depending on the tree species. The period between complete replanting of new stock can be longer than 20 years. In addition to their fuel value, energy crops can also be planted for erosion control, soil remediation, and as nutrient filters that prevent nutrient run-off from land into waterways. Developing economical energy crops could greatly increase biomass supplies for power generation.

Framework for Action

A Five-Year Plan

Strategies constitute a framework for action. The following table highlights the Biopower Program's research, development, and field verification projects and initiatives that are putting the strategies into motion. They are grouped by major strategic area, but in some cases they combine several strategic elements. Additional information is available at the Biopower Website of the U.S. Department of Energy at www.eren.doe.gov/biopower.

	Years 1-3	Years 4-5
Technology		
Cofiring	Complete three cofiring demonstrations using residues.	Complete one additional cofiring demonstration.
	Complete modifications for a closed-loop system in Iowa using switchgrass and perform two cofiring tests for power.	Complete Iowa project.
	Attain cumulative planting of 1,000 acres of willow for a closed-loop system in New York and complete first willow cofiring test.	Complete New York project.
	Initiate gasification cofiring demonstration.	Complete gasification cofiring demonstration.
	Extend cofiring investigations to natural gas.	Follow up as needed with designs, development, and field verification projects.
Modular Systems	Award two to five prototype system subcontracts, and complete prototype testing; award one to three integrated system subcontracts.	Complete integrated system testing projects.
Gasification	Achieve sufficient hours of operation to provide confidence for next-generation plants.	Continue into field verification.
	Award advanced concept design, and test projects for alternatives to the gasification options.	Continue into field verification.

	Years 1-3	Years 4-5
Thermochemical R&D	Complete testing of internal combustion engine on medium calorific value biogas, initiate micro-turbine testing, complete construction and field testing of tar analyzer.	Apply combined model of equilibrium and kinetics to gasification and combustion processes; complete fuel cell testing program.
Feedstock Development	Update resource database for biomass crops and residues; establish progeny trials from willow breeding; initiate biomass feedstock supply logistics R&D; investigate barriers to expanded resource use.	Demonstrate 20 percent or greater yield increases in short rotation trees and grasses in regional trials; add at least 5,000 acres or more in operational-scale and research plantings; demonstrate increased residue availability with improved supply infrastructure at two to four sites.
Environment	Continue environmental evaluations on all aspects of operational scale biopower production projects. Complete life-cycle analysis (LCA) of Iowa switchgrass cofiring project. Conduct LCAs of modular and agricultural residues to energy projects. Analyze impacts of crop residue removal and of urban residue use; evaluate soil carbon, water quality and habitat effects of energy crop plantings. Add forest residue removal studies; evaluate biomass role as riparian buffers for water quality.	Continue environmental evaluations on all aspects of operational scale biopower production projects. Obtain data to update LCA as field tests are performed. Continue crop residue removal studies and soil carbon effects studies.
Outreach	Assist the private sector in developing strategies and methods to overcome non-technical barriers to the deployment of biopower systems by providing information and cooperation on economic, regulatory, social, environmental, informational, and financial factors.	Continue and expand outreach efforts to facilitate the public acceptance of biomass through improved education and information. Incorporate new data and experience into the outreach efforts.

Biopower Program Websites

DOE Biopower Program—
http://www.eren.doe.gov/biopower

Bioenergy Feedstock Development Program—
http://bioenergy.ornl.gov/bfdpmain.html

Regional Biomass Energy Program—
http://www.ott.doe.gov/ofd/biomass.html

U.S. Department of Energy Office of Fuels Development—
http://www.ott.doe.gov/biofuels

NREL's Thermochemical Users Facility—
http://www.nrel.gov/research/industrial_tech/tcuf.html

Sandia Combustion Research Facility's Multi-Fuel Combustor Laboratory—
http://www.ca.sandia.gov/CRF/GenInfo/facilitydesc_3.html

National Energy Technology Laboratory—
http://www.netl.doe.gov

Energy Efficiency and Renewable Energy Network (EREN)—
http://www.eren.doe.gov/

U.S. Department of Energy Bioenergy Initiative—
http://www.eren.doe.gov/bioenergy_initiative/

National Biobased Products and Bioenergy Web Site—
http://www.bioproducts-bioenergy.gov/

U.S. Department of Energy Industry of the Future: Forest Products—
http://www.oit.doe.gov/forest/

U.S. Department of Energy Industry of the Future: Agriculture—
http://www.oit.doe.gov/agriculture/

Key Terms

Biomass—
Any organic matter that is available on a renewable basis, including agricultural crops and agricultural wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic plants.

Biopower—
Electric power derived from biomass.

Bioenergy—
Any power, fuel, or chemical product derived from biomass.

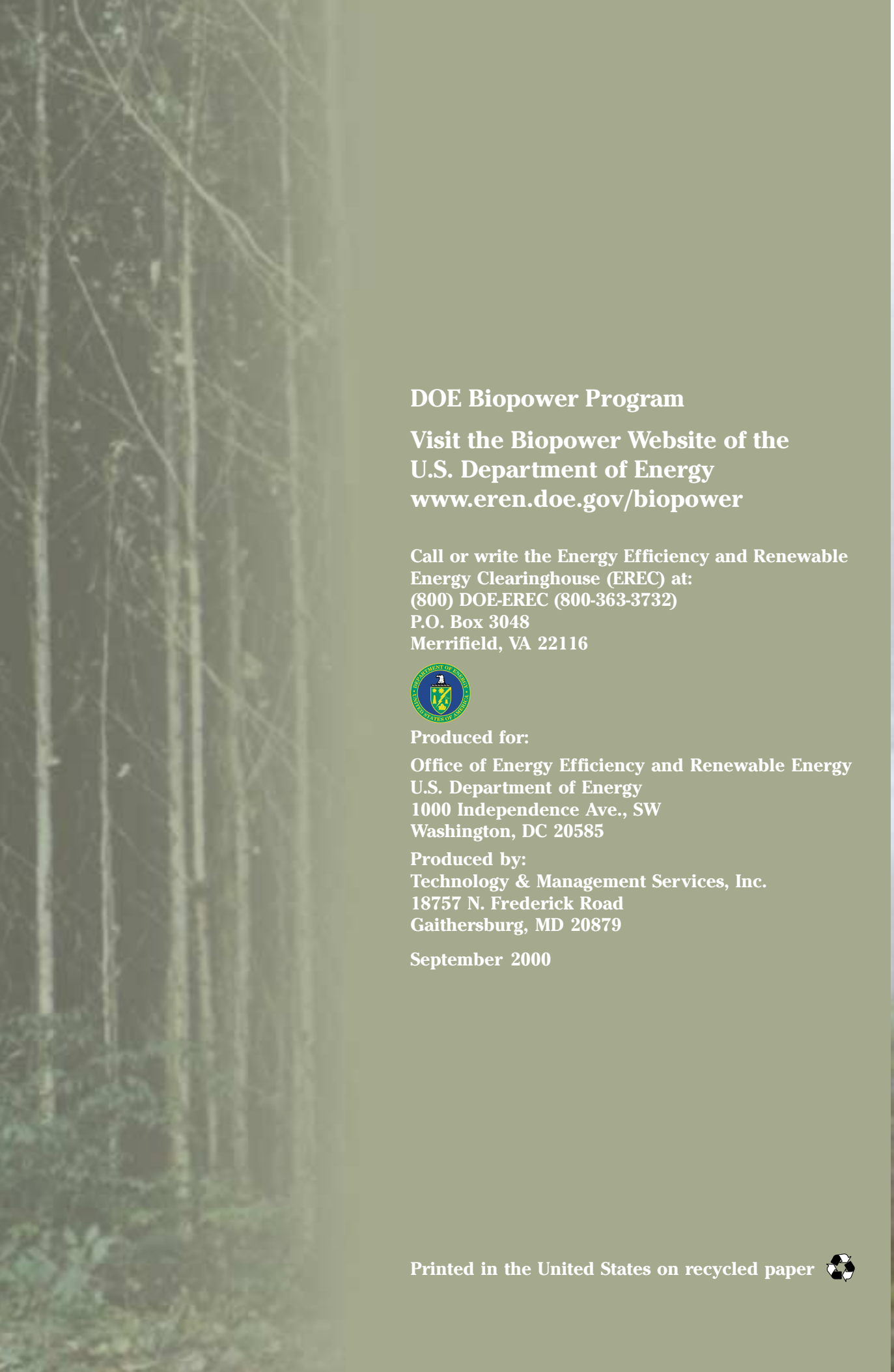
Biobased Products—
Any product including fuels, electricity, chemicals, adhesives, lubricants, and building materials developed from biomass.

Biomass Feedstock—
Biomass for use as a raw material or component in the production of bioenergy or any other useful product.

References

U.S. Department of Energy. Energy Information Administration. *Annual Energy Outlook 2000. Washington, D.C., 1999.*

U.S. Department of Energy. Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies. *Scenarios of U.S. Carbon Reductions. Washington, D.C., 1997.*



DOE Biopower Program

Visit the Biopower Website of the U.S. Department of Energy www.eren.doe.gov/biopower

Call or write the Energy Efficiency and Renewable Energy Clearinghouse (EREC) at:
(800) DOE-EREC (800-363-3732)
P.O. Box 3048
Merrifield, VA 22116

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